6

PUTTING IT ALL TOGETHER

6.1 INTRODUCTION

This chapter explores the problem of course design

The previous chapters of this instructor's manual have examined in detail some of many individual puzzle pieces involved in creating an excellent introductory physics course. There comes a time, however, when one has to actually assemble the pieces into some kind of coherent whole. My goal in this chapter is to discuss with you the process of creating a course structure where the individual pieces positively reinforce each other in creating an environment where students can be excited about physics and where real learning can take place.

This is an extremely difficult problem, and I do not claim to be any kind of genius about how to solve it elegantly (some of my early course designs were indeed quite awkward). On the other hand, the IUPP process has given me impetus to experiment with various course structures, and I have done this with my eyes open and in conversation with a number of people who are thoughtful and gifted physics teachers. My various failures in this process have highlighted for me a number of things that do not appear to work, and I can at least warn you about these. Moreover, more than eight years of experiments do seem to have yielded some clarity about the questions to ask and maybe even a few positive insights about how to do things well.

An overview of this chapter's sections

Section 6.2, reviews briefly why creating a good course structure is so important, and **section 6.3** lists a few course design principles that I have found useful. **Section 6.4** displays a sample course information sheet and syllabus that one might hand out to students on the first day of class, and **section 6.5** interrogates this particular course design using the twenty questions raised in section 1.3 of this manual. **Section 6.6** explores some issues of course design using the homework scheme as an example. **Section 6.7** offers a generalized approach to creating a lesson plan for a class session. Finally, **section 6.8** offers some encouragement for you to contribute to the process.

The devil is in the details

One of the surprising things that has emerged with stark clarity from my experience with the IUPP trials is that transferring a course structure from one institution to another is very difficult. This is mostly because what makes a course work or fail in a given situation often has less to do with the course's major structural elements and more to do with the tiny details of how these structures are implemented in context. This is one of the most important reasons, I believe, that large educational reform movements often fail.

Therefore you will have to adapt the ideas in this chapter for your context

This means that any specific course structure that I might propose may well not work for you (even if it works well for me at Pomona) because your students are different than my students, your institutional culture is different than mine, the layout of your room and your building is different than mine, and your particular teaching style is different than mine. You will *have* to adapt thoughtfully the ideas that I present in this chapter to make it fit your situation. What I hope that this chapter does for you is provide an illustration (a worked example, if you like) of the *process* of creating a workable course design and raise the issues that you will have to resolve.

6.2 COURSE STRUCTURE IS IMPORTANT!

Good course structure is the key to success

Let me remind you how important good course design is. My experience clearly underlines (and research that I have read and heard corroborates) that student attitudes and their performance are affected only weakly at best by the content of the chosen text (or how cleverly that content is presented), but are affected very strongly by the way the course is structured. I talked in section 1.2 about how the structure and pace of a traditional course can drive a student with the best of intentions to mindless behaviors that get the job done and earn the high grades. In the one situation I know of where a *Six Ideas* course almost failed, the primary problem was a structural problem having to do with the way that homework was assigned and graded. The flip side is that in the situations I know of where students are unusually happy and/or performing extraordinarily well (for example, in Priscilla Law's *Workshop Physics* course, in Eric Mazur's classes at Harvard, or in Dwight Neuenschwander's lab program), the success of these courses clearly has a lot to do with the ways they are structured.

My point is that a course's *structure* usually determines whether it succeeds or fails. I would *like* to tell you that buying a particular text (*Six Ideas*, to take an arbitrary example) will make your course a certain success, but claiming that would be false to everything I have learned from the IUPP process. I hope that I have written a text that will make it *easier* for you to create a successful course, but it is still all too easy to create a *Six Ideas* course that fails to do the job.

Creating a better structure than the traditional course may not be that hard

On the other hand, the *Force Concept Inventory* data discussed in section 1.6 of this manual (corroborated by numerous other studies) makes it clear that the traditional course structured in the traditional way essentially *automatically* fails to do the job of helping students really understand and use physical concepts. This appears to be true independent of how great the teacher is or how happy the students are. The good news in this is that a few thoughtful modifications of course structure (particularly those that increase the time devoted to active learning) may be able put you a long way ahead of the traditional course!

6.3 COURSE DESIGN PRINCIPLES

Course design principles supported by experience

As I said before, participating in the IUPP project has given me the excuse to experiment with a number of course designs. Here are some of the principles that this experience has taught me to value.

(1) **Reward the right behavior.** This is the most crucial design principle of all: if you do not reward students for learning and/or doing the kind of work that will help them learn, then your course structure will work against your goal. In spite of the fact that this principle is fairly obvious, it is one of the most difficult, I have found, to carry out in practice. Students are very creative about finding ways to work around the structure so that they do not have to work so hard. If your course structure does not make it essential to do things the right way and virtually impossible to take shortcuts, some students will quickly find the shortcuts.

(2) **Make all assignments and classes really worthwhile.** One of the reasons that students work so hard to find the shortcuts is that they are busy (or at least perceive themselves to be so). Therefore, they react very negatively to assignments and class sessions that they feel waste their time.* It is necessary to go beyond just simply deciding whether an activity is valuable to seriously weighing what activities deliver the *greatest* value for the time spent. For example, working with computers can eat up enormous amounts of time for the amount of physics learned, unless the computer activities are designed *very* carefully. Consider the bang delivered per minute spent on all activities.

(3) **Build in flexibility.** No matter what structure you lay down, there will be students who will beg for exceptions, and the number of exceptions you will be asked to handle goes up geometrically with the number of students in the class. I have learned, however, that one can significantly reduce the time one spends evaluating exceptions by building flexibility into the course structure. For example, allowing students to drop a few homework assignments without penalty, or providing specific ways that students can make up missed work

means that students can deal with the minor disruptions of their schedules within the structure of the course and thus without needing to request an exception. This can save a lot of *your* time if you do it right!

(4) **Remember that students are not all alike.** A large introductory class generally is populated by students with widely-ranging abilities, backgrounds, and needs. Some learn better from reading; others learn better by hearing or seeing. Some work well in groups; others are loners. Some think verbally; others visually. Part of what it means to create a flexible course design is to make it possible for a large range of students to do well in the course. Evaluation contracts (see section 4.9) are one important way of doing this, but keeping one's eyes open for other ways to keep flexible is also important.

(5) **Make rules that you can enforce happily.** I have an unfortunate tendency to set up fairly strict sanctions in my course structure (because I want to maintain high standards) but then waive the sanctions for a good sob story (because I am also compassionate). This is not really fair to the students who are following the rules, and it also quickly gets around that I am a bit too kind-hearted, which undermines the trust students have in me and increases the rate of misbehavior. I have found it important to discipline myself to only state rules that are compassionate or flexible enough so that I am really willing to enforce them in almost every conceivable circumstance.

(6) **Use an absolute grading scale.** (I mentioned the importance of this in chapter 4.) Competition between students is something to avoid in a class where students often working together. An absolute grading scale sets standards for students and also helps you distance yourself somewhat from the grading, so that you can be more of an ally to the students instead of their enemy. I try to describe my absolute grading scale clearly enough so that every student can compute for themselves what their grade is at any time in the course, and then promise them that I will only adjust their grade *upward* from that (if I decide that a certain test was too difficult).

(7) **Keep it simple!** Some of my earliest course designs were baroque in their complexity: students were rewarded in complicated and distinct ways for a whole range of activities. Both they and I found such structures confusing and hard to work with. I quickly learned to appreciate a lean structure where a few cleverly-designed elements work together to address many needs and objectives in a simple and flexible manner. Creating such a design is more of an art than a science, but powerful elegance is a design goal well worth striving for. (My current designs are better than they were, but still could be improved in this regard!)

6.4 AN EXAMPLE COURSE STRUCTURE

The next four pages illustrate a possible *Six Ideas* course structure

The following four pages show the course information sheet and syllabus for a hypothetical *Six Ideas* course at Pomona College for 2002/2003. This meant to serve as a concrete example of one possible *Six Ideas* course structure, and indicates how I would probably teach the course (1) were I teaching it alone, so that I did not have to coordinate the structure with a colleague, and (2) were I not on sabbatical.

This course structure uses the "1.3-pass" grading system described in section 4.8 of this manual, the lab program described in section 5.4, and embraces most of the guidelines described elsewhere.

A note about a peculiar part of the fall syllabus

(**Note:** The upper class majors at Pomona always perform a surprise Halloween show for the introductory students on the class session before Halloween; in 2002, this falls on October 30. Designating Nov. 2 as a "catch-up" day on the syllabus is my way of reserving space for the show without giving away what will happen. Otherwise, I would have probably put the catch-up day at the end of the semester: the tail end of unit *R* can be tricky for students.)

PHYSICS 51b —— GENERAL INFORMATION —— 2002-2003

Instructor	Office	Phone	E-mail	Office Hours
Thomas Moore (9 am)	Millikan 129	x18726	tmoore@pomona.edu	To be determined

About the course: Physics 51a and 51b comprise a two-semester calculus-based introduction to physics. This nontraditional course is based on a model curriculum developed at Pomona for the Introductory University Physics Project (IUPP), a national project funded by the National Science Foundation and the American Institute of Physics.

Texts: Moore, Zook: *Physics 51 Laboratory Reference Manual* (used last semester, too)
Moore: ***Six Ideas That Shaped Physics***

Other supplies you will need: (1) a good **scientific calculator** (preferably with statistics functions), (2) a **purple or green pen**, and (3) a large (9" ¥ 12", not 8" ¥ 10") quadrille-ruled **lab notebook**. You will also find a ruler, a 3-ring binder, and a stapler handy.

Web site, Class Display Case, and File Folders: We will post course news, computer programs, important links, error notices, etc. on the Physics 51 web site at `http://www.physics.pomona.edu/phys51/` . Everyone in this class will have a personalized file folder in a file box on the table in the Millikan hallway in front of the display case labeled “Physics 51”. If you consent, graded work will be returned to your folder.

A Metaphor: Research has shown that learning to do physics has more in common with learning to play a sport or musical instrument than it does with memorizing a body of information. This course is structured to fit this metaphor. This means that you should consider class sessions and homework to be *practice*, quizzes and exams *league games or recitals*, and your instructors and TAs *coaches.* You will receive credit for both practice and performance.

Assigned readings: Class sessions will primarily involve interactive activities where you practice using the concepts you have read about in the text. *Therefore, it is essential to have read the assigned reading BEFORE coming to class*. The syllabus shows the chapter assigned for each class day in boldface type.

Daily Participation: Class activities will *always* assume that you have read the assignment and may involve mini-quizzes, group problem-solving, table-top experiments, and/or presentations of group work before the class. Participation is required, as the class will be interactive, and depends upon having students present to be effective. Penalties for not attending class will be assessed as part of your homework grade (see below).

Daily Homework (pre-class warmup): *At the beginning* each class you will hand in (to a tray in the classroom) solutions to two homework problems associated with the reading assignment for that day to a tray in the classroom. These problems will be graded on a 5-point scale using the following general guidelines:

5: good effort with correct results *and* reasoning
4: a good effort with minor errors or a fair effort with no conceptual or math errors
3: a good effort with modest conceptual errors and/or math errors or a fair effort with minor errors
2: a fair effort involving modest conceptual errors or a good effort involving serious conceptual errors
1: a very poor effort
0: no initial effort

A good effort involves at least *some* English explanation and/or use of appropriate diagrams along with calculations, and/or some recognition of an implausible result. If you cannot solve a problem after a reasonable effort you should at least indicate in words what information appears to be missing, and/or where and why you are stumped. Be sure to write *something* for every part of a problem. You will earn a maximum of 2 points if you do the wrong problem.

Graded problems will be returned to your personal file folder by the next class session, and solutions will be posted on both on the website (`http://www.physics.pomona.edu/phys51`) and in the glass display case for the course. You may use the solutions and your colored pen to *correct* any problems that you wish to (even if you did not submit an initial effort). Be sure to correct effort deficiencies as well as math errors. Submit corrected work to the mailbox labeled “Physics 51a corrected work” or bring them to class and submit to the “Corrections” tray, in either case no later than **one week** after the problem was originally due. Your correction will be evaluated on a 2-point scale

2 = everything is suitably corrected,   1 = some items uncorrected,   0 = major issues uncorrected

These correction points will be added to your initial score (up to a maximum of 5) yield your final problem score.

Since part of the point of the daily homework is to ensure that you are fully prepared for class activities, I will not accept *initial* efforts that are late or if you are not present for class (unless you have a written excuse or we have made prior arrangments). Late *corrections* also seriously gum up the grading process (which is challenging to manage as it stands) and so cannot be accepted without prior arrangement. However, I will drop the three lowest daily homework problem scores in each unit before calculating your homework grade, to give you the flexibility to deal with alarm-clock failures, normal illnesses, field trips, family emergencies, big papers, unexpected romances, etc.

Weekly Homework: In addition to the daily problems, three weekly problems will be due each **Monday** at the beginning of class. These problems will help you to review the previous week's material, and typically will be more challenging than the daily problems. You need not be present for class to earn credit for weekly problems.

One of these weekly problems will be a *collaborative learning* (CL) problem. There will be two collaborative learning sessions on Sunday nights (at 7:00 p.m. and at 9:30 p.m. respectively) if you would like to work in groups on the CL problem (or if you need help on the other problems).

I expect daily problem solutions to be somewhat sketchy, but on the weekly problems, I would like you to make an effort to write a solution that is coherent and clear as well as correct. I will therefore grade these problems on an 8-point scale, with the extra three points devoted to quality-of-presentation issues such as the following: Does the solution provide adequate diagrams and/or explanations of the model? Does the solution use units and vector notation correctly? Does the solution avoid doing algebra with numbers? The grading rubric for these points looks like this:

3: great presentation
2: minor presentation problems
1: major presentation problems
0: extremely poor presentation

Use the posted problem solutions as examples of excellent style (though in many cases, you can write an excellent solution in fewer words).

Just as with the daily homework, you may correct weekly homework problems: simply submit them to the corrections box sometime before the class session a week after the problem is originally due.

Collaborative Learning Bonus Points: To encourage you to experience the benefits of attending the collaborative learning session, I will give you ***two bonus homework points*** for each CL session you attend (up to a total of 6 points) during unit C. (This can also help you earn back points you may have lost as you adjust to the homework system). You will earn your credit if you attend the session on time, sign the sign-in sheet, and participate in the discussion. (If you regularly cannot attend either Sunday evening session, let me know.)

Tests and quizzes: The "exam" for each unit will consist of a set of conceptual problems (like the two-minute problems in the text) worth 20 points and two or three short essay problems worth a total of 30 points. The conceptual part of most unit exams will be administered as two 10-minute, closed-book, closed-notes quizzes offered at the end of selected class sessions (see the syllabus), and the essay part as an hour exam. (For units *R* and *T*, *both* parts of the exam will be offered together during exam week.) On the essay parts (and the entire unit *R* and *T* exams) you will be able to use a half a sheet of paper (covered on both sides with any information you want) as a "cheat sheet." All numerical constants that you need will be provided. There will also be a short (and mostly conceptual) comprehensive final exam each semester. The first semester, this exam will emphasize newtonian mechanics; during the second semester the comprehensive exam will emphasize electricity and magnetism

Grading scale: All grades in this class will be based on a fixed scale, so that you do not need to compete with each other. You can determine your grade on any homework assignment, lab, or exam by dividing what you earned (with bonus points) by what you *could* have earned (*not* counting bonus points), multiplying the result by 20, rounding to the nearest integer, and consulting the chart below:

Integer:	20	19	18	17	16	15	14	13	12	11	10	9	£ 8
Grade:	A+	A	A–	B+	B	B–	C+	C	C–	D+	D	D–	F

If average class performance for any item is particularly low (indicating that the item was unusually difficult) I may adjust grades to be *higher* than this scale would indicate, but I will never adjust your grade to be *lower*.

Course grades will be calculated as follows:

Fall Semester			
Unit	Homework	Exam	**Total:**
C	12%	12%	24%
N	12%	12%	24%
R	12%	12%	24%
		Lab	22%
		Comp. Final	6%
		Total	100%

Fall Semester			
Unit	Homework	Exam	**Total:**
E	12%	12%	24%
Q	12%	12%	24%
T	12%	12%	24%
		Lab	22%
		Comp. Final	6%
		Total	100%

Also note: **You will fail the semester if you receive an F for the lab OR for two or more units.** See the laboratory manuals for information about lab grading.

the laboratory manuals for information about lab grading.

SYLLABUS FOR PHYSICS 51a — FALL 2002

		Monday	Wednesday	Friday	Lab
			4 Introduction to the Course	6 Reading: **C1** 21st Century Physics C1B.2, C1S.4	
S E	<u>C1R.4</u> C1S.2	9 **C 2** Vectors C2B.5, C2S.4	11 **C 3** Momentum C3B.4, C3S.4	13 **C 4** Particles and Systems C4B.3, C4S.7	Inertial Mass
P T	<u>C2R.3</u> C3S.2 C4S.5	16 **C 5** Conserv. of Mom. C5B.6, C5S.9	18 **C 6** **Quiz** Intro. to Energy C6B.4, C6S.3	20 **C 7** Potential Energy C7B.4, C7S.1	Catapult Danger Zone
	<u>C5R.1</u> C6S.6 C7S.9	23 **C 8** Force and Energy C8B.6, C8S.4	25 **C 9** Rotational Energy C9B.8, C9S.4	27 **C 10** Thermal Energy C10B.5, C10S.5	Energy in Springs
	<u>C8R.1</u> C9S.8 C10S.7	30 **C 11** Energy in Bonds C11B.7, C11S.9	2 **C 12** **Quiz** Impacts C12S.2, C12S.6	4 **C 13** Angular Momentum C13B.9, C13S.2	Thin Lens Optics
	C11S.7 <u>C12R.2</u> C13S.6	7 **C 14** Conservation of AM C14B.5, C14S.1	9 **N 1** Newton's Laws N1B.7, N1S.3	11 **UNIT C EXAM**	Uncertainty of The Mean
O C T	N1S.4	14 **N 2** Vector Calculus N2B.8, N2S.5	16 **N 3** Forces from Motion N3B.8, N3S.3	18 **N 4** Motion from Forces N4S.3, N4S.8	Rolling Balls
		21 FALL BREAK due 10/23: N2S.7* N3S.6* <u>N4R.1*</u>	23 **N 5** Statics N4S.11, N5S.4	25 **N 6** **Quiz** Linear Motion N6S.5, N6S.9	Lens Systems
	N5S.8 <u>N6R.2</u> N6S.4	28 **N 7** Coupled Objects N7B.12, N7S.5	30 **N 8** Circular Motion N8S.2, N8S.4	1 (Catch Up Day)	Simple Pendulum Newton's 3rd Law
	N7S.6 <u>N8R.1</u> N8S.6	4 **N 9** Noninertial Frames N9S.2, N9S.3	6 **N 10** Projectile Motion N10S.6, N10S.12	8 **N 11** Oscillatory Motion N11B.5, N11S.1	Pendulum (cont.) Noninertial Frames
	N9S.8 <u>N10R.2</u> N11S.9	11 **N 12** **Quiz** Intro to Orbits N12B.7, N12S.7	13 **N 13** Planetary Motion N13S.9, N13S.10	15 **R 1** Principle of Relativity N13S.7*, R1B.4, R1S.6	Relativity Lab (Pendulum First Drafts due)
N O V	(study)	18 **UNIT N EXAM**	20 **R 2** Synchronization R2B.1, R2S.4	22 THANKSGIVING BREAK	
	R1S.6 <u>R2R.2</u>	25 **R 3** The Nature of Time R3B.4, R3S.3	27 **R 4** The Metric Equation R4B.7, R4S.4	29 **R 5** Proper Time R5B.6, R5S.2	(Discuss Pendu- lum report with lab staff)
	R4S.5 <u>R4R.2</u> R5S.8	2 **R 6** Transformations R6S.1, R6S.4	4 **R 7** Lorentz Contraction R7B.5, R7S.7	6 **R 8** The Cosmic Speed Limit R8B.7, R8S.2	Mass Dependence of the Pendulum
D E C	R6S.5 <u>R7R.3</u> R8S.8	9 **R 9** Four-Momentum R9B.6, R9S.9	11 **R 10** Conserv. of 4-Mom. R10S.1, R10S.5	13 OPTIONAL REVIEW	
		17 18 (8 am) UNIT R EXAM and FINAL (51a-2)	19 20 (8 am) UNIT R EXAM and FINAL (51a-1		

<u>Underlined</u> problems are the collaborative learning problems.
*"Weekly" problems not due on Monday (for various reasons).

SYLLABUS FOR PHYSICS 51b — SPRING 2003

	HW due	Monday	Wednesday	Friday	Lab
JAN			22 (no reading due) Introduction	24 Reading: **E1** Electrostatics E1B.8 E1S.2	
JAN	E1S.7 E1S.9	27 **E2** Electric Fields E2B.8 E2S.2	29 **E3** Electric Potential E3B.6 E3S.4	31 **E4** Conductors E4S.1 E4S.2	Batteries and Bulbs
	E2S.10 E3R.2 E4S.9	3 **E5** Driving Currents E5B.8 E5S.3	5 **E6** **QUIZ** Analyzing Circuits E6B.8 E6S.2	7 **E7** Magnetic Fields E7B.8 E7S.3	Voltage and Resistance
FEB	E5S.9 E6R.1 E7S.10	10 **E8** Magnets and Currents E8S.2 E8S.7	12 **E9** **QUIZ** Symmetry E9B.9 E9S.4	14 **E10** Gauss's Law E10B.8 E10S.2	Electric Motor. Oscilloscope.
	E8R.3 E9S.6 E10S.6	17 **E11** Ampere's Law E11B.9 E11S.3	19 **E12** Electromagnetic Fields E12B.6 E12S.6	21 **E13** Maxwell's Equations E13B.1 E13S.3	RC Circuits
	E11R.3 E12S.4 E13S.2	24 **E14** Induction E14B.8 E14S.1	26 **E15** **QUIZ** Intro to Waves E15B.8 E15S.2	28 **E16** EM Waves E16B.6 E16S.2	Building a Blinker
MAR	E14S.5 E15S.7 E16R.2	3 **Q1** Standing Waves Q1S.2 Q1S.4	5 **UNIT E ESSAY EXAM**	7 **Q2** Wave Nature of Light Q2B.5 Q2S.6	Standing Waves*
	Q1S.11 Q1R.2 Q2S.12	10 **Q3** Particle Nature of Light Q3B.4 Q3S.5	12 **Q4** Wave Nature of Matter Q4B.4 Q4S.3	14 **Q5** The Facts of Life Q5B.9 Q5S.4	Interference
	SPRING BREAK				
	Q3R.1 Q4S.5 Q5S.2	24 **Q6** The Wavefunction Q6B.1 Q6B.3	26 **Q7** **QUIZ** Bound Systems Q7S.1 Q7S.6	CESAR CHAVEZ DAY	(Discuss Standing Waves report with lab staff)
	Q6S.2 Q6S.9 Q7R.1	31 **Q8** Spectra Q8S.5 Q8S.9	2 **Q9** Atoms Q9B.2 Q9S.3	4 **Q10** Schrodinger's Equation Q10B.5 Q10S.2	CD Track Separation
APR	Q8R.2 Q9S.5 Q10S.8	7 **Q11** Energy Eigenfunctions Q11B.1 Q11S.3	9 **Q12** **QUIZ** Introduction to Nuclei Q12B.7 Q12S.7	11 **Q13** Nuclear Stability Q13B.5 Q13S.7	Spectrum of Hydrogen*
	Q11S.5 Q12R.1 Q13S.2	14 **Q14** Radioactive Decay Q14S.8 Q14S.11	16 **UNIT Q ESSAY EXAM**	18 **T1** Temperature T1B.4 T1S.9	Radioactivity
	Q13S.8 T1R.1	21 **T2** Ideal Gases T2B.1 T2S.6	23 **T3** Gas Processes T3B.4 T3S.7	25 **T4** Macro & Microstates T4B.3 T4S.3	(Discuss Hydrogen report with lab staff)
	T2S.5 T3S.4 T4S.8	28 **T5** The Second Law T5B.4 T5S.7	30 **T6** Temperature & Entropy T6B.5 T6S.8	2 **T7** Mysteries Resolved T7B.2 T7S.3	Squiggle-Ball Thermodynamics
MAY	T5S.3 T7S.8 T6R.2	5 **T8** Calculating DEntropy T8B.7 T8S.9	7 **T9** Heat Engines T9B.6 T9S.7	9 OPTIONAL REVIEW	
			13 8 am UNIT T EXAM and FINAL (51b-1)	16 8 am UNIT T EXAM and FINAL (51b-2)	

LABORATORY FORMAT — PHYSICS 51b page 4

Structure of a Normal Lab: Each lab has a specific, easily-stated *goal* described on a single sheet of paper handed out at the beginning of lab. You will work in teams of *three* (aided by your lab-staff "helper") to design an experiment to accomplish that goal with the available equipment. You will be graded as a team on the basis of the quality of your responses to questions posed during interviews with a lab staffer. We will strictly enforce an *upper* limit of three people per lab group.

Pre-Lab Assignments. For some of lab sessions (mostly in the first semester), you have assigned reading and exercises to complete (see the syllabus). Be sure to complete these assignments and work the exercises *before* coming to lab. Your work on the exercises will be checked at the beginning of lab.

Helpers* and *Graders*:** A certain lab staffer will be designated as your ***grader for each specific lab and will conduct the interviews. A different staffer will be designated as your ***helper***. Your helper's job is to respond to your questions, pose leading questions, protect your safety, nudge you to do the right thing, and generally be as helpful as possible without telling you what to do. Your helper knows what your grader is likely to ask, and will help you prepare for the interviews. Your helper will also be looking to see that each of you pulls your weight. Both roles will rotate among the lab staff during the semester so that each team is evaluated fairly.

Team Roles: During each lab, you should designate a team member to be responsible for each of the following roles. You will rotate these roles so that each team member has a chance to practice each role.

1. The **Recorder** is responsible for keeping a careful record of lab procedures, observations, and measurements in his or her lab notebook. This will serve as the team's record of the lab.
2. The **Procedure Supervisor** is responsible for understanding the group-developed procedure, making sure that it is followed, and generally keeping the group on task and working efficiently.
3. The **Skeptic** is responsible for worrying about what the grader will think and anticipating questions he or she will ask, for making sure that uncertainties are analyzed carefully and work is done correctly, for making sure that everyone completely understands the lab completely, and for thinking about safety issues.

The Interviews: Ask your helper for a ***procedure interview*** when, after playing with the equipment and talking with your partners (but before you begin serious data-taking), you think that you have devised a workable procedure for addressing the lab's goal. Your helper will ask you some questions to make sure that your procedure is realistic and that you have anticipated possible problems. Ask for a ***checkout interview*** when you have accomplished the lab's goal and feel that you all fully understand it and what your results mean. Your grader will look at the Recorder's notebook and ask specific team members questions so as to explore your team's understanding of the lab. He or she will also ask you to reflect on how you could have done the lab better, both with regard to lab procedure and to working together as a group.

Interview Grades: Your checkout interview grade will depend on the quality of the answers provided by *whoever the grader asks*. Please do not respond to a question unless you grader asks you to (even if you know the answer). At the end of each interview, the grader will offer some feedback about how well you did. The weights assigned to the pre-lab exercises and the final interview will vary from lab to lab, but all labs will be worth 20 points total.

The *Simple Pendulum*, *Standing Waves* and *Spectrum of Hydrogen* Labs. These three labs are like a normal lab except (1) you can assign the team roles as you see fit (rather than following the strict rotation), (2) your helper will conduct your checkout interview (so as to give you feedback) but will not grade them, and (3) you will be graded *individually* on first and final editions of a ***full lab report*** you write for the lab. The first edition of each lab report will be due at the beginning of lab the week after you do the corresponding lab. The following week, you will have an interview with your grader, who will give you a grade (out of 20) and make suggestions about how you can improve your work for the final edition. The final edition will due at the beginning of lab a week after your interview and will be graded on a 40-point scale.

Lab Grade Warnings. Missing two or more normal labs or failing either final report will cause you to fail the lab, **which means failing the course**. If you must change lab periods during a given week or make up a lab, *please arrange with your lab instructor in advance*. You may make up **one** *unexcused* absence per semester for 60% credit by arranging with the lab coordinator to come to a lab session later in the week (40% credit if the lab must be made up the following week), but this grace will only be extended once. *Unless you arrange with your grader in advance,* a first draft for a full lab reports loses 2 points per day for the first four days it is late (not counting the weekend) and cannot be accepted after that. A final draft loses 4 points per day for the first 5 days, and 1 point per week thereafter (if it is not turned in by the final day of class, you will fail the lab and thus the course).

6.5 ANALYSIS OF THE STRUCTURE

Course structures that...

Let us analyze how this structure addresses the twenty course-structure questions first raised in section 1.3.

...get students to come to class prepared

(1) How can I most effectively ensure that students come to class prepared? This is one of the most difficult problems to solve elegantly. For this design, I chose to assign daily problem sets graded using the "1.3-pass" homework scheme described in **section 4.8** of this manual. I tried to choose problems that are relatively straightforward to do and yet are hard to do without reading important parts of the chapter. Preliminary results suggest that this approach works fairly well. According to an anonymous questionnaire, students report being prepared for the class sessions that they attend an average of 80% of the time. The class average of the fraction of classes each student estimates attending times the fraction of those classes for which the student was fully prepared was over 0.70. While these numbers could be improved, they are better than for any other method I have tried so far.

...keep tough homework from being discouraging

(2) How can I structure homework assignments so that students can practice tough problems and learn from their mistakes without becoming discouraged?" This question is addressed by the 1.3-pass homework scheme (see **section 4.8** of this manual). I have never found any other system that addresses this crucial problem nearly as well.

...keep the classroom actively involving

(3) What can I do in the classroom that will help students effectively practice physics thinking skills, particularly in a large class? The part of the structure that ensures that students read the book is also crucial to make active learning possible. While these things are not explicitly part of the structure, I will also habitually use two-minute problems (see **section 3.4** of this manual), interactive demonstrations (see **section 3.6**) and some of the other activities described in **chapter 3** to keep the class active. See also section 6.6 to see a fruitful way to plan a class session.

...help encourage students to ask good questions

(4) What can I do to make students feel more free to ask questions and participate in class discussion? In the past, I have sometimes given bonus points for people who submit questions via email before class, but while this generates some *very* interesting questions, it also makes for a lot of work managing and grading the questions. Currently, I simply make it clear during the first day that I am open to questions, and will make every effort to answer questions submitted by email ahead of class. I also follow the guidelines for answering questions discussed in **section 3.8** and for fruitful discussions in **section 3.9**.

...help locate difficulties that students are having

(5) How can I find out what difficulties students are having with the text and effectively address those difficulties in class? Doing two-minute problems is a reasonably effective way of doing this, and creating a positive atmosphere for questions helps (see **section 3.8**).

...keep nonparticipators from being disruptive

(6) How do I handle students who don't want to participate in activities? How should I handle students who don't come to class at all? Where in the past, I used an evaluation contract system (see **section 4.10**) to provide resistive students a way to opt out of the class-intensive structure, I now use example class activities to make it *very* clear on the first day of class what the class will entail, so that people who do not feel that they can do what is required have an opportunity to drop the course. The evaluation contract system does not seem to me to be much more effective at present.

(7) Do I want to *require* students to attend? Do I want to give them points for attending? If I don't want to do either of these things, what can I do to make students *want* to attend? This class structure *implicitly* requires attendance (though not perfect attendance) through

...encourage class attendance

the homework system. When we used a variant of this scheme during the spring of 2002, we had the highest attendance rates recorded in recent times (roughly 90%, though not everyone was on time). I generally resist schemes that require attendance, but this appears to be necessary given the current culture at Pomona College. The scheme seemed to work reasonably well, and though there were clearly some students who were mildly resistant to doing activities in class, they did not prove disruptive.

...reduce pressures to lecture

(8) How can I resist the natural internal and external pressures to lecture? Again, the structures that encourage students to read will help reduce the pressure. Creating organized, efficient, and worthwhile class-sessions with the help of the guidelines in **section 6.6** also will help, as does constantly reminding myself about the things discussed in **section 3.2**.

...help develop appropriate student study skills

(9) How can I help students understand and appreciate the differences between this course and other science courses that they may have taken, and help them adjust their study habits appropriately? The course structure is sufficiently divergent from other science courses that they are likely to see that their standard approaches to studying may not work. Even so, I reinforce this on the first day by talking about *why* the course is different and what the benefits to them are likely to be.

...help make demonstrations actively involving

(10) How can I make demonstrations an opportunity for active learning? This is not explicitly part of the structure, but I use the two-minute problem structure to get students involved with the demonstration by predicting and then interpreting the outcome. See the discussion of interactive demonstrations in **section 3.6** for more details.

...set an appropriate pace

(11) How quickly should I move through the material? Can my students handle the design pace of the course (see below), or does the pace need to be reduced? If so, what is the best way to reduce the pace? The syllabus as designed specifies the maximum pace. Because Pomona College recently cut a day from the spring semester, I have had to drop a chapter from one of the last three units; I have chosen to drop Q15 to stay within the design pace of one chapter per 50-minute class session.

...use computers appropriately

(12) How can I use computers most effectively in the course? How should I use computers during class sessions? Should I assign computer work outside of class? What kind of computer-based assignments work? Again, this is not explicitly part of the structure, but I will use computers in at least units *N*, *Q* and *T*, following the guidelines in **section 3.7**. Some of the assigned homework uses these programs.

...create collaborative learning opportunities

(13) How can I structure recitation sections to encourage collaborative problem-solving and motivate students to participate? The current structure has collaborative learning recitation sections as an intrinsic part of the course structure. Giving a modest number of bonus points seems to be an effective way to get people to attend these sections: when we have used bonus points, attendance is about 60% of the class, but when we have not, the attendance is more like 20%. However, an experiment we did last year showed that dropping the bonus points for the second half of the course did not affect attendance much: after being inticed to come by the points initiall, students apparently found them valuable enough to keep coming even without the points. Therefore, this year, I am going to try offering bonus points only at the beginning. While this is not an explicit part of the structure, I try to choose the student mentor to be someone who is enthusiastic, approachable, and interested in teaching. I then train him or her to help students without giving them answers, and I also attend the first CL session and give some feedback. Finally I give that person copies of the solutions to the collaborative learning problems so that they don't lead students astray.

...set standards for and manage homework

(14) What standards do I want to enforce for the quality of work on homework assignments? What do I want students to get out of these assignments? How can I most efficiently assign grades and manage the paper-flow associated with such assignments? The issue of homework-solution standards is one of the trickier issues that I have explored during the last decade. On the one hand, if a student simply writes down an answer, that is not enough. On the other, students do not solve problems in the same logical and sequential style as experts, and expecting too much from them (particularly on daily problems) leads to frustration and anger. I have found by experience that (1) it is important to keep expectations on daily problems pretty low as long as students *some* display evidence of correct reasoning, and (2) it is important that all expectations be clear, easy to describe (e.g. "Don't do algebra with numbers") and reasonably easy to execute. The next time I teach the course, I plan to do some very specific classroom exercises during the class sessions on chapters C3, C4, and C5 to sensitize students to certain specific style issues (particularly the perennial problem of correct vector notation).

The 1.3 pass homework scheme outlined in the course plan is the most natural plan I have ever developed for keeping grading easy and paper flowing smoothly. Having separate, clearly marked trays and/or boxes makes the paper flow *much* easier to manage and the grading system is pretty easy to apply.

...set up flexible rules for late assignments

(15) What kinds of rules do I want to establish for late assignments? How can I build an appropriate amount of flexibility into these rules? These rules are specified in the course information, and are the product of many years of successive refinement. The only kind of case outside these parameters that occasionally come up is a person who has been chronically absent and/or has not turned in much homework, but suddenly comes to his or her senses. I am often more flexible about giving some credit for late work under such circumstances than the rules would imply. Ironically, though, I have found such students don't get to their "crisis point" soon enough if the rules are not clear and pretty stiff.

By the way, we have found that taking off a certain number of points per day that an assignment is late loses all its effect after a certain amount of time. You will therefore notice that the lab writing assignments, for example, stop depreciating after a while. This reflects my actual practice: once a paper is more than a week late, I find that I am more interested in getting the paper at all (and keeping the student from failing utterly) than I am about the particular time that I get the paper. I have found that system of time-limited depreciation, therefore, really helps when I try to convince serious procrastinators that they can still gain something by handing in the work.

...create good exams

(16) How can I create exams that (a) reward successful application of physics thinking skills, (b) are long enough to test a variety of such skills, (c) are short enough so that students can complete them in a reasonable time, (d) are hard enough to be challenging, (e) are easy enough so that students don't get discouraged, and (f) are nonetheless easy to grade? Note that the structure specifically serves notice that both conceptual understanding and problem-solving skills will be valued. Dividing each unit exam into two quizzes and an essay test spreads out the examination process over several days. This students to keep abreast of the course, makes the "exam" long enough to test a number of student skills and yet short enough so that students should be able fairly easily complete the test in the allotted time. Finding the balance between "too easy" and "too hard" is an art that every teacher has to develop in their own context. The example exams provided in **chapter 10** of this manual are pretty appropriately balanced for Pomona students. They also illustrate some techniques for making such exams fairly easy to grade.

...foster student enthusiasm about physics

(17) What kinds of things can I do to get my students excited about physics? Both research and abundant anecdotal evidence suggests that the single most important thing that an instructor can do to *generate* student enthusiasm is to *be enthusiastic* yourself! Being enthusiastic does not guarantee that your students will learn better, but they will like it, and everyone will be happier and more productive. I hope that *Six Ideas* discusses enough interesting physics to provide a base for this enthusiasm, but it is worth diverging from the text every now and then if you find something else to be charged up about. The IUPP evaluation suggested that good demonstrations that are both entertaining and educational also inspire student enthusiasm. Other things that might help include taking a field trip to a playground, amusement park or a national lab, having your upper class majors do a show of humorous physics skits, inviting the students to a barbecue, challenging the intro chemistry class to softball, etc. An off-the wall class session or lab can really relieve the tedium. Students still remember the classes where I stood on my head to make a point, sang a humorous song about a bricklayer's experience with a practical Atwood machine, played my fiddle, and so on. Be creative about keeping students off guard!

...keep students upbeat about how they are graded

(18) How can I help keep student attitudes about evaluation positive (without giving all of them As)? The course structure gives students ample course credit for effort (particularly on daily homework), uses an absolute but fairly generous grading scale, makes more time for the exam by spreading it out, and provides some bonus points and other degrees of flexibility. If the students understand exactly how they are being evaluated, feel that they are being evaluated fairly, and find their assigned work to be worthwhile, they will feel pretty good about the evaluation process.

...create a good laboratory experience

(19) What are my goals for the laboratory portion of the course? How can I design laboratory exercises that address these goals? See **chapter 5** for an extensive discussion of this issue and the logic behind the laboratory syllabus.

...contribute to an elegant and workable design

(20) Finally, how can I address all of these concerns while keeping the course structure simple, flexible, and elegant? Considering some designs I have created in the past, I consider any course design that (oounting the lab) can be fully explained on three sides of a sheet of paper pretty simple, considering the large number of unusual things that the design asks students to do. I have tried to balance functionality with elegance ()making each element play multiple roles if possibl), and the structure described is the best that I can do at the moment. Creating leaner, more elegant, and more functional course designs is always an interesting problem to me, though; if you think you have some useful ideas that haven't occurred to me, I'd love to hear them!

6.6 A DESIGN TUTORIAL: HOMEWORK GRADING

As a simple example of the kind of decision-making that needs to go into creating a good a course design, I'd like to examine a possible modification to the homework grading scheme. The grading scheme just described evaluates any submitted corrections using a different point scale than the initial effort. Might it make sense to evaluate the corrected homework using the same 5-point scale as the initial effort, and then average the scores of the initial and corrected problem to get the final score for that problem? For example, a person who makes a good effort on the initial submission, but commits some serious conceptual errors might get a 3 initially but a 5 on the corrected version, and so earn a 4 overall. What would making this change imply?

The proposed change would have the main effect of decreasing the incentive for students earning a 3 or 4 on their initial effort (which will be the majority of scores) to submit a correction, as such a student could earn a 5 after the correction in the old system but only a 4 or 4.5 in the proposed system. The possiblity of earning a perfect score has much more psychological draw than bumping up the score by an increment, even when the numerical consequences for the final course grade are small.

The proposed change will therefore have the likely secondary effects of reducing the number of corrections submitted, increasing the importance of the initial effort, and decreasing the average homework grades somewhat. All of these secondary consequences have positive and negative aspects. Reducing the number of corrections submitted could save grading time, but also give fewer students the positive experience of checking their work. Increasing the significance of the initial effort and lowering the average grade is probably OK for the weekly problems, but could run the risk of increasing student frustration with the daily problems, making assigning homework ahead of class seem more unfair.

It might seem unfair to an *instructor* to give a perfect score to a student who made significant errors on the initial effort, but the point of the homework scoring system (in my opinion) is to encourage effort, not to separate better from weaker students (the exams do the latter). The original scheme provides that incentive more forcefully for the majority of students.

At the other extreme, the proposed scheme treats people who did not submit *any* initial effort more leniently than the original scheme, as a person earning a 0 on the initial effort could earn a 2.5 as a final score instead of a 2. Personally, I think that someone who simply paraphrases a posted solution has learned *less* than half as much out of the problem as a person who has made an honest initial effort, and the score should reflect that.

For these reasons, I think personally that the original system is marginally better for my students. This, however, illustrates the kinds of issues that one has to weigh carefully when designing a course structure.

6.7 DESIGNING A GOOD LESSON PLAN

After one has established the course structure, the task is to create lesson plans that support the structure and foster active learning. When I sit down to write a lesson plan, I find it helpful to use a general class-session framework to guide my thinking and ensure that I focus on the important issues. After experimenting with a number of frameworks, the following framework seems to me to be the most comprehensible, flexible, and practical.*

Divide each class into three 15-minute blocks

As a first approximation, imagine a 50-minute class-session to be divided into three 15-minute blocks (this leaves 5 minutes for transition time). Such a block provides roughly needed to pose two (or maybe three related) two-minute problems, gather responses, and fully discuss any issues raised. It also represents roughly the time required to do a typical interactive demonstration or work a typical example problem. Thus a 15-minute block thus represents a first approximation to the time required for a typical class activity.

(1) Consider reserving a block to help prepare for the next chapter

The first step of the framework is actually to consider the *next* reading assignment. Are there any demonstrations or activities worth doing to help prepare students for that assignment? It is often important that students have an opportunity to *discover* an idea before they read about it in the text.

For example, section C3.2 in unit *C* describes a series of collision experiments from which one can draw conclusions about the nature of momentum. This section will be much more meaningful to students if they have seen the experiments demonstrated before they do the reading. Therefore, it is good to reserve the last block of the class session on chapter C2 to perform and discuss the experiments described in the text. Other text chapters, however, do not particularly need such advance preparation. In short, if you can think of an appropriate demonstration or other activity that might help students prepare for the next reading assignment, reserve the last 15-minute class block for that activity.

*This framework is an extension of the one proposed by Eric Mazur in his book *Peer Instruction: A User's Manual*, Upper Saddle River NJ: Prentice-Hall, 1997.

(2) List issues (one per remaining block) that are most worthy of class time

The next step of the framework is to consider the *current* reading assignment and list the issues (concepts or skills) discussed in that chapter that you think are most important for students to practice, one issue per available block. The issues that you choose will usually those issues you consider to be the most crucial, but sometimes it is worthwhile to spend time on a less central issue that you know is difficult for students if more important issues are easier.

What if you have more issues to discuss than blocks remaining in the class? Part of the beauty of a course structure where the text is the primary source of information is that that you really don't have to talk about *everything* in class. Following this framework helps ensure that you talk about those things that are most crucial and/or difficult; you can generally let the text cover the rest.

(3) Choose activities that best address each issue

Once you have chosen the issues I want to explore in class, consider the activities that will best help students practice each issue. The default would be to select one or maybe two two-minute problems that best address the issue and spend the block discussing those. But some issues are better handled using interactive demonstrations, example problems, or other activities. Considering the options discussed in chapter 3 of this manual, what activities might most effectively address the issue at hand?

(4) Do some fine adjustments of block durations

After you have chosen the activities for each block, the final step is to verify that the block durations are appropriate for the activities chosen. Discussing a single two-minute problem often really takes only 10 minutes or so, while doing a difficult example problem interactively might take 20 minutes. This means that fitting the blocks into the into the class period may involve transferring a few minutes between blocks and/or modifying the activities to fit the time available. Alternatively, if you have an issue left over that you think is pretty crucial, you might consider whether you could adjust activities so that you can divide the class into three 10-minute blocks and a 15-minute block, for example.

Remember, the text is standing behind you!

It is important in this final step to be realistic. My experience is that it is very easy to underestimate the time needed to complete a given activity. Keeping at least 5 minutes of class time unscheduled provides some buffer against such inevitable errors, and I strongly recommend doing this.

If you do run out of time, again remember that the text is backing you up. Think carefully about whether this issue is important enough to warrant a block of time in the next class session: if it is not, just let it go. In general, I find that when the class structure successfully gets students to read the material, I feel much less guilty about dropping issues to keep up with the syllabus.

Keep records of how each block went

Keeping good records about how much time a given block actually required can also help one plan more realistically for the future (I wish I had done this more carefully in the past!). Indeed, one of the great advantages of this block-based framework is that one can keep a notebook of useful class blocks with practical information about the time required and suggestions for future improvement. If your colleagues also use this framework, then you can share suggestions about great class blocks.

Share your block ideas with colleagues on the web

One of my fond hopes is to find a good way for those of us teaching *Six Ideas* will be able to exchange ideas for creative class blocks with each other. Please contribute your great ideas by sending me email!

6.8 FINAL COMMENTS

Send me your class information for access to the instructor's web page

As discussed in the Quick Guide (chapter 0), I hope to maintain a *Six Ideas* instructor's web site that will provide access to the parts of this manual that provide problem solutions and sample exams. I also hope to post some example lesson plans. This site is password-protected, because one would not necessarily want students accessing things like the reading quizzes. If you are an instructor, please send me the information specified in the Quick Guide, so that I can send you instructions on how to access this site.

Also send me things that you think would be helpful for others

Also, I would like to post articles and/or tips about *your* experience with *Six Ideas* that you think others would like to hear. Please send me such items!